PERCEIVED BARRIERS AND OPPORTUNITIES TO ENGINEERING TECHNICAL COMMUNICATION IN SELECTED AIR FORCE ORGANIZATIONS

THESIS

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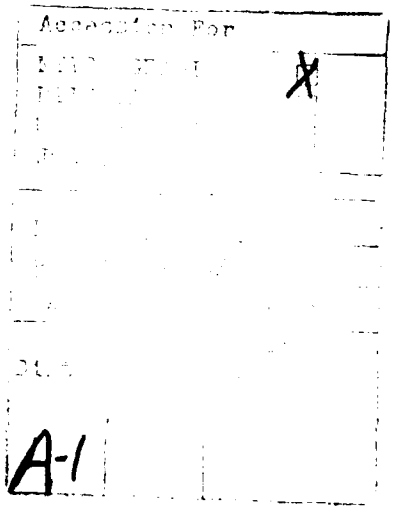

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THESIS

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Master of Science in Systems Management

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Abstract

Once successfully used, mature (empirically proven) technologies are rarely diffused (remarketed and used) on subsequent systems. One of the greatest barriers to the diffusion of technology is a lack of widespread awareness that a technology exists. The objective of this research was to identify technical communication barriers and opportunities, as perceived by selected Air Force Systems Command (AFSC) and Logistics Command (AFLC) engineers, that affect the diffusion of technologies into their organizations. A survey of 86 selected AFSC and AFLC engineers was conducted in support of the above objective. Overall, the results of the study support the findings of previous research. Recommendations are offered to help improve the widespread awareness of (and hopefully the subsequent use of) mature technologies by defense engineering organizations.

PERCEIVED BARRIERS AND OPPORTUNITIES TO ENGINEERING TECHNICAL COMMUNICATION IN SELECTED AIR FORCE ORGANIZATIONS

I. Research Problem

Introduction

The scarcity of acquisition funding, coupled with stringent Air Force Reliability and Maintainability (R&M) 2000 goals, demands that successful (mature) technologies be exploited as much as possible. However, once successfully used, technologies are rarely diffused (re-marketed and used) on subsequent systems (2; 39). A 1974 study by the Federal Council for Science and Technology noted that "the practice of adapting technology to a secondary use is outside the laboratories' mission responsibility and is frequently lacking or not developed" (25). A possible reason for the slow movement of technology might be insufficient technical communication and information-seeking behavior with sources external to the organization. The Air Force Coordinating Office for Logistics Research (AFCOLR) sponsored this research into the problems of technology diffusion in an effort to increase the use of mature technologies.

A major study area of technology diffusion concerns the movement of technology from the laboratory to an initial application-- this is called technology transition. The area of technology transition has received much attention in the last ten years (12; 17; 21; 36; 40; 51). This paper does not purport to examine this avenue of technology movement and associated communication factors per se; instead it attempts to examine the methods of information exchange that program engineers use to seek information on mature (empirically proven) technologies for problem solving purposes.

A literature review and discussions with AFCOLR personnel have resulted in the identification of many potential barriers to technology diffusion (2; 22); however, one of the greatest barriers is simply a lack of widespread awareness that a technology exists or knowledge of its risks and benefits. Rogers and Brown believe that an important relationship exists between the amount of widespread knowledge about an innovation and its rate of adoption (8:6; 41:235). Rogers adds that the existence of effective communication networks within a society results in faster rates of diffusion and adoption" (41:236) than within societies with limited communication networks. He quotes the results of five separate studies that support this assertion (41:235). Liker and Hancock conclude from their studies that a lack of time and information are the two most

serious barriers to the engineering effectiveness of a major US auto manufacturer (31:86).

Both Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC) have the ability to incorporate technology into systems in development or production. However, the barriers to technology awareness may differ between the two commands. Colonel Darrell Grapes, in a speech delivered for the Deputy Chief of Staff, Headquarters Air Force Logistics Command, argued that communication problems with system developers and a general lack of technical knowledge within the Air Logistic Centers (ALCs) are primary barriers to technology transfer within AFLC. He attributes the lack of knowledge to a limited awareness of industry state-of-art and ALC priorities on production that do not encourage innovation (2:27).

Research Objective

The objective of this research is to identify technical communication barriers and opportunities, as perceived by selected Air Force Systems Command and Logistics Command engineers, that affect the diffusion of mature technologies from external sources into their organizations.

Investigative Questions

Three questions were addressed as follows:

Investigative Question 1. What is the frequency of use and perceived importance of information sources and channels

used by Air Force engineers when they seek technical information?

Investigative Question 2. What communication barriers do Air Force engineers perceive that impede access to sources of technical information external to their organizational units?

Investigative Question 3. What communication opportunities do Air Force engineers perceive that would enhance the diffusion of mature technologies into and out of their organizational units?

Methodology

Samples of engineers from two sources were studied: (1) engineers within an Aeronautical Systems Division (ASD) System Program Office of Air Force Systems Command at Wright-Patterson Air Force Base, and (2) engineers within a Warner-Robins Air Logistics Center (WR-ALC) System Project Office at Robins Air Force Base. A two-case study approach was used to compare the respective barriers perceived by engineers from each organization.

A survey questionnaire was administered to a census of engineers within each organization, to determine their information-seeking behaviors and their perceived barriers to technical communication. The survey listed criteria that the literature review revealed as potential barriers to technical communication, and asked the respondents to indicate which ones they perceived as major barriers. The

respondents were also able to suggest other conditions they perceived as barriers. Hypothesis tests were used to compare the source frequency of use, source importance, and respective barriers perceived by the WR-ALC organization as opposed to those perceived by the ASD organization. The respondents were asked to suggest ways of enhancing the flow of technical information into and out of their organizations.

Limitations

This research did not consider the technical communication involved when transitioning a new (unproven) technology from a research laboratory to an initial or "first use" application. Only communications that affect the application of mature technologies were considered. Mature technologies are defined as those technologies that are now used in fielded systems or technologies that have transferred from a laboratory to an initial application (i.e., efforts funded by category 6.4 Engineering Development funds [ASD] or Class IV Modification BP 11 and 15 series, and Sustaining Engineering EE/IC 583 [WR-ALC] funds). Due to the unique blend of military and civilian engineers within the selected ASD and WR-ALC program offices and the thesis emphasis on mature technologies, the reader should not statistically infer the results beyond the organizations surveyed. The reader, however, could

logically infer the results of this research cautiously to other defense organizations.

II. Review of Literature

Introduction

The review of literature begins with examples of the technical communication problem, followed by the definition of technology diffusion and its relationship to technical communication. A brief discussion of the selected communication model and associated factors, as well as the perceived barriers that affect information flow, is presented.

The Problem

Many reasons exist for studying the barriers to communication and their effect on the movement or transfer of technology. A major concern is that of ensuring combat capability. Padula notes:

> Why did it take the Air Force over 14 years to accept a technology that provides leak-free hydraulic fittings? There were 350,000 of these fittings flying on Navy F-14 aircraft, for 14 years-- with no leaks. This performance is even more impressive when you consider that these fittings were exposed to both the stresses of a fighter environment and corrosion problems of the salt spray on a carrier. The implications of this Air Force "oversight" are tremendous in peacetime, but could be critical in wartime. . . . It was by chance that the Air Force even discovered this technology. . . . (39:1)

The hydraulic coupler technology was eventually discovered by the Air Force during a 'Blue Two' visit (an effort to bring system developers into contact with organic system maintenance personnel) sponsored by AFCOLR. As a

result of their efforts, this technology is now used on the B1-B and C-5B aircraft. The primary reason for the slow diffusion of this technology was apparently a simple lack of awareness -- a problem in technical communication.

One would think that good ideas would sell themselves. Unfortunately, this does not often happen. Rogers illustrates this point by discussing the efforts of the British Navy to combat scurvy (41:7). Apparently, on long voyages, scurvy was the biggest killer of ship personnel. Rogers notes that although an Englishman conclusively demonstrated in 1601 that citrus fruit cured and prevented scurvy, the British Navy did not conduct their own tests until almost 150 years later. Indeed, the Navy did not adopt this innovation until 1795. Rogers lists several possible reasons for the slow adoption of citrus, including competing remedies for scurvy and a lack of prestige of the researchers (41:8). He does not include an estimate of the number of men who must have died of scurvy during the 194 years required to diffuse and adopt this knowledge.

Background

Any research on information transfer must recognize that not all information is obtained in a deliberate manner. Salasin and Cedar are careful to caveat their communication research with the fact that information is often stumbled upon in unexpected, inadvertent ways (43:4). They conclude that the occurrence of an exchange of information is often

triggered by the simple availability of information (43:62). A good example of this is the Air Force engineer's chance discovery of the Navy's hydraulic coupler technology previously mentioned.

Technology Diffusion

Technology diffusion (also called technology transfusion by AFCOLR) is "the process by which an innovation is communicated through certain channels over time among the members of a social system" (41:10). Rogers notes that "diffusion is a special type of communication, in which the messages are concerned with a new idea" (41:6). The concept of a new idea implies that risk is involved -- risk is identified in many studies as a principal barrier to technology transfer because of management cost and schedule constraints (12:32; 40:10). However, Cormier and Salvucci contend that a balancing conflict is necessary among cost, schedule, and technical excellence (12:122; 32:21).

For military systems development purposes, Padula defines technology transfusion (diffusion) as the "beneficial horizontal movement of technology to one or more systems after its initial application" (39:2). Therefore the concept of risk is minimized because empirical data is available from the "proven" first application of the technology.

Stewart attempts to distinguish between the meanings of technology "transfer" and technology "diffusion" by stating

that commercial firms wish to encourage "diffusion" or widespread use of a technology-related product, while at the same time restricting the "transfer" of the understanding of the technology itself (47:72). Others (13; 32; 38; 41) do not distinguish between the terms. Although Stewart's distinction between use and understanding is valid (26:63), the terms "diffusion" and "transfer" are used interchangeably in this author's research.

Technical Information

The explosion of technical information in our society today is well-documented (4; 17; 50). Allen notes:

> The tremendous increases in recent years in the amount of research and development performed in the world has resulted in a concomitant increase in the amount of information to be communicated, presenting the user with the difficult problem of plowing through a morass of available information to reach the information pertinent to his problem. . . . The technologist must obtain his information either through the very difficult task of decoding and translating physically encoded information or by relying upon direct personal contact and communication with other technologists. (4:5,7)

A logical point to initiate discussions of technical communication is to posit a model that represents the flow of information. This researcher selected a simple model used by Berlo (23:59) and modified by Jolly and Creighton (27:21). This model is selected due to the emphasis that it places on the user end of technology transfer (34:16). User emphasis is important because the thesis focus of mature technologies infers that a direct sponsor-user link does not

normally exist, as it otherwise should in transitioning technologies (12; 36).

The model has three parts: a source, which feeds information through a channel to a receiver. Jolly and Creighton present a list of intrinsic (formal) and extrinsic (informal) factors that affect the flow of information from source to receiver (34:20). McCorkendale states:

> The "intrinsic" factors are easier to conceptualize and are objectively measurable. They deal with mechanics and procedures used to index, store, retrieve and disseminate information. The "extrinsic" factors deal with interpersonal communications, personal feelings about a knowledge source, and perceptions about one's organization, supervisors and peers. (34:17)

Intrinsic Factors

Intrinsic factors include information documentation, distribution, the receiver organization, and the nature of the project (34:26-30). The project factor is concerned with the transition of technology from research to an initial application and therefore will not be discussed.

Documentation. Documentation refers to how information is defined, organized, and presented. Two additional variables -- language and format-- relate directly to the ease of use of the information (34:21). Engineers often use language that is not universally understood by persons outside their own organization (4). McCorkendale notes:

> . . . .often an area will be very well documented, yet not be well documented for transfer. . . . information can be expressed in many ways, each understandable or useable to a different group of people. If research documentation is in a form understandable by the

> perceived potential users, then the chance for eventual utilization of that information may be greatly enhanced. (34:22,24)

A major problem of documentation is that professional literature can inhibit the transfer of technology. First of all, symbolism can vary between organizations, as noted above. Second, Allen argues that engineering professional literature is often written in a scientific format that is "utterly incomprehensible to the average engineer" (4:73). He illustrates this by stating that the journal articles "often rely upon mathematical presentations, which can be understood by only a limited audience" (4:73). He adds that "no efforts are made to interpret or translate the material into a form that the average practicing engineer can understand or use" (4:73).

Allen is not attempting to criticize the mental capacity of the average engineer. He merely points out that many engineers have been away from an academic environment for ten years or more, and are not required to use the levels of mathematics and physics in their daily activities that are shown in many journal articles.

A second problem lies in the area of maintaining and expanding written technical information. This derives from what is commonly known as the fundamental nature of technology (4:39; 5:695; 43:7). This concept posits the idea that scientists (pure researchers) are more apt to use and add to written information sources than engineers

(people who apply technology). Allen points to the fact that publication often serves as the embodiment or culmination of a scientist's work... while an actual physical product is more often the result of an engineer's efforts (4:40). Therefore engineers are less likely to either document or read of the outcome of a technological accomplishment than are scientists.

In an effort to document the availability of mature technologies, AFCOLR/TT has initiated a newsletter program of "TechTIPs" designed to enhance awareness of mature technologies. Each TechTIP contains a brief description of a technology, its benefits and drawbacks, and a point of contact (3).

A third problem concerns ownership of technological documentation. Some defense weapon systems are acquired by the government without associated data rights. If a commercial firm has developed the technology in question, then firm rights-in-data restrictions may prevent the government from disclosing the technology to other government agencies unless the government has purchased the rights-in-data. These rights often represent a firm's "bread and butter," and as such, can be prohibitively expensive. A related problem is the issue of government security restrictions--- unclassified technologies, when associated with highly classified systems, can become classified themselves (25).

Distribution. Distribution refers to the channel through which information flows (34:24). Chakrabarti et al. define a channel as "the means by which an information package is moved from one point to another" (9:84). They note that channels can include people, organizations, and technological mediums. Some forms of information distribution channels are telephones, mail, television, radio, libraries, information specialists both within and outside of the organization, and workshops or seminars. Indeed, one WR-ALC organization hosts bi-weekly meetings with local contractors in an effort to disseminate technical information among contractors and the Government (6).

An additional distribution form is the movement of people through job reassignment or temporary labor (34:25). People who change jobs often diffuse new ideas and technologies (8:27; 30:49). Recognizing this, some organizations have initiated personnel rotation policies within the various departments of their firms (33:17).

Source and channel accessibility are a key measure of the capability of a distribution system (49:68). McCorkendale notes that distribution does not truly occur unless the information has been received and understood (34:24). The barrier of capacity limitations of the receiver to receive and process the sheer volume of available information is well-documented (4). One form of distribution that is becoming increasingly popular as a

solution to the information explosion is computer databases (34:25). These include federal data bases such as the National Technical Information Service (NTIS) and the Defense Technical Information Center (DTIC), and commercial data bases such as Lockheed's Dialog system. Database systems have numerous benefits, including enhanced exchange of technology through greater access to information from a wide variety of sources, and the ability to filter relevant information from the tremendous volume of information available (24:106). DTIC's Current Awareness Bibliography service provides biweekly bibliographies of new technical report acquisitions related to user-specified areas of interest, to any defense engineer who wishes to subscribe. However, Hubbard reports that in a study of some 9000 Army engineers and scientists, only 213 subscribe to the service (24:111).

Computer databases have their share of problems. For example, although Department of Defense (DoD) Directive 3200.12 requires that DoD components submit technical reports and summaries of ongoing efforts to DTIC (50), database personnel report that they continually have problems obtaining state-of-art information. A federal study in 1975 of the Defense Documentation Center (what is now DTIC) concluded that "the identification, location, and the mechanisms for attaining such information in printed form were the greatest obstacles to a smooth flow of defense

technical information" (15:25). A 1985 study of DTIC use by Army research and development engineers reached similar conclusions (24:108).

A second reason for the difficulty of using computer databases involves the ways that information is added to and organized within the databases. A potential user often must use a system of keywords (descriptors) to identify the area of required information within a given database. A communication problem then occurs when the keywords have different meanings for different users (4:7; 26:63). Indeed, anyone who has attempted to use a computerized information retrieval system would probably attest to the amazing variety of information obtained under what would appear to be a "universally defined" keyword.

A third problem concerns the delays for receipt of paper copies of documents ordered from database services. These delays sometimes consume weeks or months between request and receipt of documentation (24:109). The delays are attributed to constrained database service budgets, user reliance on paper reproduction done by the database service, and lack of user on-line document printing capabilities (24:110).

Cormier and Salvucci report that contractors are a fundamental element in the movement of technologies (12:102). They note that the contractor forms a third party loop for assisting the transition of emerging technologies

from the laboratory to a product division (12:121). One could presume that the contractor may also play an important role in the movement of mature technologies.

Organization. The receiver's organization can impact the flow of technical information. Triscari notes: "Different organizational designs have developed with distinct characteristics and different efficiencies for processing information" (49:67). He cites a study by Burns and Stalker that shows information flow within mechanistic (highly formalized) structures is more restricted than information flow within organic (relatively informal) organization structures (49:66-67).

The nature of an organization's reason for existence and associated resistance to change is often cited as a primary organization barrier (4; 26; 32; 41). Colonel Grapes' mention of AFLC ALC emphasis on system production (as compared to AFSC emphasis on development) infers that the motivation for personnel to dedicate themselves to improve system quality through technology is limited (2:27). McCorkendale quotes a study by Schon that claims that organizations are constantly in a state of change conflict. Although most organizations are continuously changing in response to environmental stimuli, each advocate of change feels obligated to behave as though the changes he introduces will be the last (34:26). The nature and extent

of the organizational conflict involved can either encourage innovation or reject change.

McCorkendale notes that the manager must carefully monitor the degree to which information flow is facilitated or blocked at various points in his organization, and recognize the reward systems which motivate or prevent the flow of information (34:27).

Cost and schedule constraints placed on the organization can hinder the movement of technologies. Cormier and Salvucci refer to a study by Spurrier that showed that the short-term orientations of key decision makers were barriers to the successful transition of technology (12:104).

Extrinsic Factors

Extrinsic factors include receiver capacity, gatekeepers, source credibility, perceived rewards, and willingness to accept change.

Capacity. Capacity refers to the ability of an organization to accept and use new or innovative ideas (34:31). McCorkendale notes that research in this area has focussed primarily on personality traits and behaviors of individuals who exhibit "early adopter" tendencies of new ideas (34:31). He mentions several personal attributes including "social status, years of education, amount of outside communication, venturesomeness, professional status, dominance, and sociability" (34:32) that are positively

related to innovativeness. Age appears negatively related to innovativeness (34:32; 44).

Organization attributes that are positively related to innovation include business size, income, and amount of external communication (34:32). However, the age of project units with stable membership within an organization appear negatively related to innovation (29).

Gatekeepers. Gatekeepers are individuals who, by nature of communication activity with both within and external to the organization, are capable of promoting boundary-spanning information flow (14; 4; 34; 43). McCorkendale notes that "the important role of the linker has been recognized by this term or another by everyone who works with technology transfer" (34:34).

Taylor conducted a five-year longitudinal survey of gatekeeper activity at a major defense research and development facility (48). His measurement criteria included seven variables: "professional affiliations, symposia attended, papers presented, and outside contacts as measures of external interpersonal contact; and publications, journals read, and patents held reflecting internal contact" (48:18). His results showed that gatekeepers "tended to be older, have more formal education, have more technical experience, have been at the laboratory and work group longer and were primarily civilians while

Gatekeeper activity is particularly vital as a means of external communication if one accepts the premise of the "law of least effort" (20:277). Several studies have shown that most people are more likely to choose an information source based on ease of use than on the amount or quality of expected information (20; 42; 43:100). In other words, information seekers are said to choose the path of least resistance. Salasin and Cedar cite a number of studies when proposing that engineers attempt to maintain knowledge and learn of new technologies mainly through oral communication with other engineers within the organization. Indeed, their own research tended to support this claim (43:99). It is usually easier to ask someone for a problem solution than it is to attempt to research literature. Following this line of tnought, it is easier to ask someone in one's own organization (regardless of that person's expertise) than it is to attempt to locate a person with relevant knowledge in an external organization (43:100).

David and Cochran discuss the concept of a communication isolate. They state that isolates "inhibit effective communication in an organization by failing to process and transmit information" (14:167). They argue that management should understand and be aware of both gatekeepers and isolates, and that effective management of these phenomena could enhance information flow into and within the organization (14:166). However, Fischer argues that the

"gatekeeper has evolved without manager intervention" (19:83), and that managers should therefore engage carefully in attempts to deliberately stimulate gatekeeper activity.

Source Credibility. Credibility refers to a receiver's perception of the reliability of a source of information (34:36). Creighton adds that source credibility is vital--a source without status is not likely to be perceived as a source at all (13:75). McCorkendale argues that a person must contend with many sources and channels of information, and that how he and his organization react to the source depends on his and his organization's perception of the source credibility (34:38).

Reward. Reward refers to the perceived and actual recognition of innovative behavior within the individual's organization (34:38). Rewards can be distinguished by two categories: formal rewards such as salary, cash bonuses, recognition and promotion; and informal rewards such as increased responsibilities and opportunities (34:39).

Rewards can be negative. If a person tries to innovate and fails, that person may be censured or even lose his job. In this case the reward is not to innovate, but to do nothing (34:39). Jung notes that a lack of reward for successful innovation can be a barrier to technology diffusion, due to lack of management encouragement (28:24). Cormier and Salvucci argue that perceived risk is a major disincentive for considering new or different technologies:

> . . . .the primary pressures on system program offices are to meet acquisition schedule and cost goals. There is little pressure (reward) to increase the performance of a system. . . . the incentive/reward system is an important factor in whether an individual will utilize new technology. (12:102,104)

McCorkendale refers to a study by Deci that indicates that informal rewards often are a more effective motivator than formal rewards (34:39). Similar rewards are perceived differently by different people. The outcome is that managers must understand the reward system as it is perceived by the individuals in their organization before the rewards can truly serve to motivate behavior (34:39).

Willingness. This element refers to an "individual's ability and desire to accept innovation or change in the organization where he works" (34:40). This researcher modified this factor to consider the individual's propensity to seek information to provide new or different approaches to his work. As noted earlier in this paper, people often follow a "path of least effort" when seeking information. This effort can relate to either physical or psychological costs (20:277). Physical costs can be measured in terms of channel accessibility and ease of use (20:272), while psychological costs involve "a revealing of ignorance on the part of the engineer among his peers" (19:72).

A manager's principal method for combating the "path of least resistance" is through the organization's reward system (12:104; 34:40).

Summary

One of the principal barriers to the diffusion of mature technology is a simple lack of awareness-- a problem of communication. Problems in communication can be traced to barriers that exist within the various intrinsic and extrinsic factors that constitute the source-channel-receiver model of communication flow. Documentation problems include nonstandard symbolism, the problems of understanding some professional literature, and a reluctance of engineers to read about or document their technical accomplishments. Problems in distribution include information overload and limited information accessibility based on difficulties of using automated databases, security, and rights-in-data restrictions. Other problems include organization priorities that limit innovation, capacity constraints, limited gatekeeper encouragement, isolate behaviors, and a lack of source credibility. Rewards are likely to be ineffective unless management understands the organizations' perceived reward system. The path of least resistance phenomenon seems to hinder an individual's willingness to seek technical information.

III. Methodology

This section describes the methods used to collect and analyze data obtained in support of this research.

Criteria for Data Source

The data source for this study was comprised of a census of 86 08XX (civilian) and 28XX (military) engineers affiliated with selected Aeronautical Systems Division (ASD) and Warner Robins Air Logistics Center (WR-ALC) program offices. Both organizations are responsible for the same overall weapon system. WR-ALC is responsible for the maintenance and upgrade of the operational components of the system, while the ASD program office is responsible for developing a new version of the weapon system. The two organizations were chosen because a) both organizations share similar engineering opportunities and product focus, b) both organizations have a fairly consistent mix of engineering specialties [systems engineers, electrical engineers, and aerospace engineers, for example], and c) the sample sizes represented by the engineers within the two organizations made statistical calculations manageable.

The two organizations were selected for convenience purposes. The exploratory nature of this research did not warrant the costs and time required to obtain random samples of all Air Force Systems Command (AFSC) and Logistics

Command (AFLC) engineers. The results of this research would determine whether further research was justified, using a true random sample of all AFSC and AFLC weapon systems engineers.

Method of Measurement

A survey, developed using portions of existing instruments (7; 24), was administered to the census of engineering personnel from the ASD and WR-ALC organizations. A survey approach was chosen for this research primarily because there was no data otherwise found to be available for answering the investigative questions; data had to be collected. Experimentation was clearly not an option as control of individuals' education, experience, and communication behavior would have been required. Objective measurement of technical communication activity (via direct observation by the researcher) was deemed to be impractical due to researcher time and cost constraints, leaving survey measurement of perceptions and opinions as the only reasonable data collection technique. Because of the desire to survey both ASD and WR-ALC engineers and the limited time available for data collection, mail questionnaires were chosen over personal interviews as the preferred survey approach.

Required actions were as follows:

1. The list of proposed barriers (derived from the chapter 2 literature review) was reviewed with eleven

selected engineers from ASD and WR-ALC as a content validity check of the selected barriers. The military (Major and above) and civilian (GS-12 and above) engineers were chosen from a variety of engineering specialties representative of the population to be surveyed. The eleven engineers were asked to provide expert opinion on the proposed survey information sources and technical communication criteria. The pre-survey is shown in Appendix A.

2. A pretest of the survey instrument for readability and format was done on seven selected ASD engineers.

3. The survey instrument (shown in Appendix B) was submitted for review and approval by Headquarters, Military Personnel Center.

4. The approved survey was delivered in person to engineers within the ASD program office. A point of contact at WR-ALC delivered the survey to WR-ALC engineers. This approach helped to maximize the response rate within both organizations. The results were designed to assure anonymity to both the respondents and their respective organizations.

Statistical Testing

The researcher initially considered a parametric analysis of variance approach for statistical calculations. The applicability of parametric statistics are contingent upon the following three assumptions (18:358) 1) the observations should be independent and randomly drawn, 2)

the observations should be from normally distributed populations, and 3) the populations should have equal variances. The first assumption was not met. The sample data was obtained via non-probabilistic means as explained in the "Criteria for Data Source" section above. Secondly, assessments for population normality [using the personal computer STATISTIX program Wilk-Shapiro statistic (45:591-611)], did not present satisfactory evidence that the population characteristics were normally distributed. Thirdly, the assumption of equal variance proved suspect after a Hartley's test for variance homogeneity was conducted on the perceived barriers (37:416). Based on the above factors, a non-parametric statistical approach was used for data analysis.

Investigative Question 1. This question addressed the frequency of use and perceived importance of sources and channels that engineers use to seek technical information. Potential information sources for the survey were derived from those found in the literature review (7):

1. Internal formal sources -- to include organization reports, department memorandums, and formal scheduled meetings (survey question 9).

2. Internal informal sources -- to include informal conversations with superiors, subordinates, and peers, and informal meetings (survey question 11).

3. External formal sources -- to include professional journals, trade magazines, technical publications, government and contractor reports, schools, and professional and trade association meetings (survey question 10).

4. External informal sources -- to include informal conversation with contractors, peers from other

organizations, and professional society contacts (survey question 12).

Each respondent ranked the perceived importance and frequency of use of each item within the four sources on a five-point scale, and was able to list additional items that were not found within the four listed sources on the survey. A composite score for each of the four sources was determined by averaging the response to each item listed under the four sources.

Wilcoxon Rank Sum tests were conducted to compare source frequency of use within three principal demographic characteristics, including a) organization -- WR-ALC versus ASD, b) years of government service -- less than fifteen years versus fifteen or more years, and c) education -- those with undergraduate degrees only versus those who had completed graduate level coursework. This approach was then repeated for source perceived importance comparisons. The analysis results are shown in Appendix C.

The Wilcoxon Rank Sum test provides a means of comparing two population distributions. A null hypothesis of no difference between the two distributions is posited, and a test statistic is calculated from the sample population data. If the test statistic exceeds a critical value (based on a selected alpha confidence level), then the null hypothesis is rejected and an alternate hypothesis (that a significant difference exists between the two populations) is accepted.

The overall alpha (probability of committing a Type 1 error) was set at 0.1. Since the Wilcoxon Rank sum tests were to be repeated for each information source, the application of a 0.1 alpha to every test would have resulted in the overall probability of Type 1 error for each set of four hypotheses being larger than the 0.1 value set for each individual test. Therefore, the Bonferroni method of dividing the overall alpha by the number of proposed tests (35:147) was used to calculate individual alpha levels of 0.025 for each test. The fairly large (e.g., 0.1) overall alpha was used because the Bonferroni technique controls Type 1 error, but does not control Type II errors well (meaning that some significant differences could be masked).

Because the Wilcoxon Rank Sum test does not indicate the magnitude or direction of differences between two populations, when differences were detected, the averages (means) of the populations were compared to assess how the populations differed.

A Kruskal-Wallis nonparametric single factor analysis of variance (ANOVA) at a 0.1 alpha was then used to determine whether significant differences existed between the overall frequency of use of each of the four sources. A second ANOVA was used to compare the overall perceived importance distributions of the four sources. If the Kruskal-Wallis tests indicated that significant differences existed, then further Kruskal-Wallis tests were conducted to determine

which of the four sources were different (1:183; 11:259). The Kruskal-Wallis test is an extension of the Wilcoxon Rank Sum test, and is used to analyze two or more independent distributions simultaneously (11:256).

The extent of gatekeeper activity and database use as external channels of information were determined. Gatekeeping activity for each individual was measured using a four-item construct (16) based on the monthly frequencies reported by respondents of:

1) The number of scientific and technical journals read (survey question 10b.).

2) Instances of seeking technical information from people outside of the organization (survey question 12).

3) Instances of providing technical information to people within the organization (survey question 13).

4) Instances of providing technical information upon request to people outside of the organization (survey question 14).

The gatekeeper questions were based on a five-point scale. Overall gatekeeping activity within each of the two organizations was obtained by averaging the individual scores for each organization. A Wilcoxon Rank Sum Test at a 0.1 alpha was used to compare the gatekeeper activity within the three demographic characteristics.

Database use information was collected using questions derived from the Army survey of DTIC (24). Database use was assessed based on the frequency of "yes" responses to the survey question 15, for both WR-ALC and ASD. Survey question 16 addressed reasons why some respondents did not

use database services. The results were reported based on the frequency of response to each potential reason.

Investigative Question 2. This question addressed the perceived barriers that impede access to sources of technical information external to one's organizational unit. Criteria that the literature review revealed as potential barriers were listed in Part III of the survey. The wording of each barrier was presented in a neutral fashion, and the five-point scale endpoints allowed the choice of each criterion as a facilitator or barrier. This was done to minimize survey bias (the distortion of responses in one direction). Each respondent ranked the perceived magnitude of each criterion (as a communication facilitator or barrier) on the five-point scale, and was able to list additional criteria that were not on the survey.

Wilcoxon Rank Sum tests were conducted to make comparisons of each barrier within the three demographic characteristics (organization, years of government service, and education). Since the Wilcoxon Rank Sum tests were to be repeated for each barrier, the Bonferroni approach was used to adjust the overall 0.1 alpha by dividing the overall alpha by the number of tests (fourteen), resulting in individual 0.008 alpha coefficients for each test. When differences were detected, the averages (means) of the populations were compared to assess how the populations differed.

A Kruskal-Wallis nonparametric single factor ANOVA was then used to indicate whether significant differences existed between the overall mean response populations for each barrier. If the Kruskal-Wallis test indicated that significant differences existed, then further Kruskal-Wallis tests were conducted to determine which of the populations were different (1:183; 11:259).

A Spearman rank correlation was done to determine whether associations existed between the perceived barriers and the frequency of use/perceived importance of each of the four information sources. This research was not structured as an experiment, and therefore one could not claim causality, should significant associations occur.

Investigative Question 3. This was an open-ended question that asked the respondents to indicate opportunities that would enhance communication with sources external to their units. This data was reported in terms of frequency of each response.

Reliability and Validity

The reliability of the survey instrument was strengthened by using questions obtained from existing instruments for a) sources of information (7), b) automated database use (24), and c) gatekeeper activity (16).

Content validity of the sources of information and proposed barriers (in an Air Force technical communication setting) were assessed by obtaining expert opinion from

eleven selected engineers from AFSC and AFLC. These engineers were asked to determine whether the proposed sources of information and barrier criteria listed in the pre-survey (Appendix A) provided adequate coverage of information sources used and problems that they perceive in external technical communication, and were asked to suggest any additional criteria that they perceived as barriers. Each barrier criterion was listed in the pre-survey on a three-point scale representing its degree of relevance to technical communication. A criterion was rejected if, based on the pre-survey responses, its relevance was determined to be less than moderate (mean value greater than 2).

The four questions that comprise the gatekeeper construct "were found by Creighton et al. to best discriminate between gatekeepers and non-gatekeepers in a survey of over 1200 members of the Navy Civil Engineer Corps" (16). Dewhirst, using Creighton's gatekeeper construct questions in a study of over 300 engineers, demonstrated a test-retest reliability of 0.75 over a 21 month period (16).

Existing literature was extensively reviewed to obtain and list potential communication barriers for this survey. In addition, all respondents were able to provide additional items they perceive as barriers. However, the outcome of this research indicates perceived barriers, and as such, may be perceived differently by different populations.

Therefore, the results of this research are presumed valid primarily for the population in question. The validity of these results should be considered carefully when applying them to other populations.

Rogers has questioned the validity of the one-shot survey as a valid measure of the behaviors related to the communication of technological information. He bases his arguments on the element of time and the issue of causality (41:112-114). He argues that the survey approach relies heavily on the ability of the respondent to recall specific actions-- but memory is often shown to be inaccurate. His second point is that "...survey data are unable to answer many of the 'why' questions about diffusion" (41:114). He recommends that research in the movement of technology involve field experiments or case studies over time to assess the issue of causality.

This author recommends that a follow-up survey be administered to the same population next year to address this issue.

IV. Results and Analysis

This chapter presents the descriptive statistics and analysis of data collected by the survey questionnaire. The demographic data is discussed, followed by the analysis of each investigative question in the order presented in chapter three.

Survey Response

The return percentages for the questionnaires are shown in Table 1:

TABLE 1

SURVEY RETURN PERCENTAGES

Category	Number Mailed	Number Returned	Return Percentage
Total	86	63	73.2%
WR-ALC	34	30	88.2%
ASD	52	33	63.4%

The respondents were sorted "ex post" by years of federal government service (0 - 14 years versus 15 or more years) and by educational degree (undergraduate versus graduate or higher) for additional analysis. The group sizes are shown in Table 2.

TABLE 2

EDUCATIONAL DEGREE AND YEARS OF EXPERIENCE

Degree	Number	Percent
Undergraduate	21	33.4%
Graduate	42	66.6%

Years Exp	Number	Percent
0-14	35	55.5%
15 or more	28	44.5%

Demographic Information

The categories of demographic data collected included the respondents' supervisory status, military or civilian status, grade level, length of Government service, time in present organization, age, and level of formal education.

Supervisory Status. This question asked the respondents to identify whether they were a supervisor or non-supervisor of other workers around them. The response distribution and percentages are shown in Table 3.

Military/Civilian Status. This question asked the respondents whether they were military or civilian. The military/civilian distribution is shown in Table 4.

Grade Level. This question asked the respondents to indicate their civilian grade or military rank. This information is shown in Table 5.

TABLE 3

SUPERVISOR DISTRIBUTION

Category	Supervisor	%	Non-Supervisor	%
Total**	10	15.8%	52	82.5%
WR-ALC**	3	10%	26	86.6%
ASD	7	21.2%	26	78.8%

** One respondent did not answer this question.

TABLE 4

MILITARY/CIVILIAN DISTRIBUTION

Category	Military	%	Civilian	%
Total**	9	14.2%	53	84.1%
WR-ALC**	3	10%	26	86.6%
ASD	6	18.1%	27	81.9%

** One respondent did not answer this question.

TABLE 5

GRADE/RANK DISTRIBUTION

Grade/Rank	Total	%	WR-ALC	%	ASD	%
GS-9/2Lt	4	6.4%	3	10%	1	3%
GS-11/1Lt	5	7.9%	3	10%	2	6%
GS-12/Capt	29	46%	17	56.6%	12	36.4%
GS-13/Major	20	31.8%	6	20%	14	42.5%
GS-14/Lt Col/Above	5	7.9%	1	3.4%	4	12.1%

Length of Government Service. The respondents were asked to indicate how many years they had performed Government service. The results are shown in Table 6.

TABLE 6

LENGTH OF GOVERNMENT SERVICE

Time	Total	%	WR-ALC	%	ASD	%
< 5 Years	17	26.9%	10	33.3%	7	21.2%
5 - 10 Yr	11	17.6%	5	16.7%	6	18.2%
11 - 15 Yr	7	11.1%	4	13.3%	3	9.1%
16 - 20 Yr	6	9.5%	5	16.7%	1	3%
> 20 Yr	22	34.9%	6	20%	16	48.5%

Time in Present Organization. The respondents were asked to indicate how many years they had worked in their present organization (defined as either ASD or WR-ALC). The results are shown in Table 7.

TABLE 7

TIME IN PRESENT ORGANIZATION

Time	Total	%	WR-ALC	%	ASD	%
< 5 Years	45	71.5%	20	66.7%	25	75.8%
5 - 10 Yr	8	12.7%	6	20%	2	6%
11 - 15 Yr	4	6.3%	3	10%	1	3%
16 - 20 Yr	2	3.2%	0	0%	2	6%
> 20 Yr	4	6.3%	1	3.3%	3	9.2%

Age Group. The distribution of ages among the respondents in the two organizations are shown in Table 8.

TABLE 8

AGE GROUP DISTRIBUTION

Age	Total	%	WR-ALC	%	ASD	%
21 - 25 Yrs	3	4.8%	1	3.3%	2	6.1%
26 - 35 Yrs	25	39.7%	13	43.3%	12	36.4%
36 - 45 Yrs	11	17.4%	7	23.4%	4	12.1%
46 - 55 Yrs	18	28.6%	7	23.4%	11	33.3%
> 55 Yrs	6	9.5%	2	6.6%	4	12.1%

Formal Education. Respondents were requested to indicate their highest level of formal education. The distribution of educational degrees among the survey respondents is shown in Table 9.

TABLE 9

FORMAL EDUCATION

Degree	Total	%	WR-ALC	%	ASD	%
High School	0	0%	0	0%	0	0%
Bachelor	21	33.3%	15	50%	6	18.2%
Graduate/No Degree	21	33.3%	5	16.7%	16	48.5%
Masters	21	33.3%	10	33.3%	11	33.3%
Doctorate	0	0%	0	0%	0	0%

Summary of Demographic Data. Both organizations reported similar percentages (10 - 20%) of supervisors versus non-supervisors. Overall, 84% of the workers of the two organizations were civilians. The grade/rank structure within ASD was significantly higher than within WR-ALC -- almost 55% of the ASD workers were GS-13/Major or above, compared to 23% of similar grade/rank within WR-ALC. This grade/rank differential may be partially explained by the respondent "length of Government service" reports -- although the length of service found within both organizations was comparable up to the 15 year point, ASD had significantly more employees who had performed Government service (48.5% versus 20%) for more than 20 years. The reported "time in present organization" was similar for both organizations -- approximately 72% of the respondents within both organizations had been there for 5 years or less. The age distribution was similar for both organizations -- the average respondent within each organization was between 26 - 35 years old. The formal education of ASD respondents was somewhat higher than the education of WR-ALC respondents. Although all of the respondents within both organizations reported having at least a bachelor degree, almost 82% of the ASD respondents reported having completed at least some graduate level education, compared to approximately 50% for WR-ALC. However, both organizations reported the same percentage (33%) of masters degrees.

Analysis of Investigative Questions

Investigative Question 1. This question addressed the frequency of use and perceived importance of sources of technical information. The hypothesis test for ordinal data (Wilcoxon Rank Sum Test) at a 0.1 overall alpha was applied to the sample data (null hypothesis = no difference between the sampled population distributions), to compare source frequency of use and perceived importance against the three demographic characteristics (organization, years of experience, and level of education).

Source Frequency of Use. The overall mean frequency of use score and the percentage of respondents using the source less than one time per month is provided for each source in columns 2 and 3, respectively in Table 10.

TABLE 10

SOURCE FREQUENCY OF USE

Source	percent not used	overall mean	reject null	higher score
A. Formal Internal Sources	19.1%	2.41	None	N/A
B. Formal External Sources	38.1%	2.19	None	N/A
C. Informal Internal Sources	6.3%	3.38	None	N/A
D. Informal External Sources	22.2%	2.61	None	N/A

If the hypothesis tests indicated a significant difference within the source frequency of use reported by the three demographical profiles (ASD versus WR-ALC, 0-14 versus 15 or more years of government experience, or undergraduate versus graduate level education), it is so indicated in column 4, and the group with the higher mean score is shown in column 5 of Table 10. More detailed information including response distributions is found in Appendix C.

The results showed that no relationships appeared to exist between the three demographic groups and source frequency of use; i.e., ASD was similar to WR-ALC, etc. However, a wide variation seemed evident between the overall mean frequency of use of each source. Therefore a nonparametric analysis of variance (ANOVA) Kruskal-Wallis test was conducted to test the null hypothesis of no difference between the population distributions associated with each information source. The resultant Chi-Square statistic (51.97) and associated p-value ($p < .001$) indicated that the populations were indeed statistically different. Additional Kruskal-Wallis tests were conducted to determine which sources were different (11:259; 1:183). The results showed that informal internal sources are used significantly more often than the other three sources. Although there were no statistically significant differences between the mean frequency of use of the other three sources, the fact that the mean use of formal external

sources is lower than the others suggests that it appears to be used the least often. These findings are consistent with the conclusions reached by Salasin and Cedar, as noted in chapter 2 of this paper.

Source Importance. The overall mean perceived importance score and the percentage of respondents who rank each source as only "somewhat important" or less is shown in columns 2 and 3, respectively in Table 11. If the hypothesis tests indicated a significant difference between the source perceived importance reported by the three demographic profiles, it is so indicated in column 4, and the group with the higher mean score is shown in column 5 of Table 11. More detailed information including response distributions is found in Appendix C.

TABLE 11

SOURCE PERCEIVED IMPORTANCE

Source	percent low imp.	overall mean	reject null	higher score
A. Formal Internal Sources	33.8%	3.14	Grad/Under	Grad
B. Formal External Sources	46.7%	2.90	None	N/A
C. Informal Internal Sources	14.5%	3.58	None	N/A
D. Informal External Sources	45.2%	3.03	None	N/A

The results indicate that significant differences exist between the importance of formal internal sources perceived by those engineers who have completed graduate level coursework or degrees, versus those who have undergraduate degrees only. The higher mean score of the engineers who have completed graduate work suggests they value formal internal sources more than engineers who have undergraduate degrees only. No other trends were evident within the demographics and the perceived importance of each source.

A wide variation seemed evident between the overall mean perceived importance of each source. Therefore a Kruskal-Wallis test was conducted to test the null hypothesis of no difference between the population distributions associated with each information source. The resultant Chi-Square statistic (21.28) and associated p-value ($p < .001$) indicated that the populations were indeed statistically different. Additional Kruskal-Wallis tests showed that informal internal sources are perceived to be more important than the other three sources. The most significant conclusion, however, is that all external sources of technical information appear to be of less importance than internal sources. In addition, formal external sources -- including all types of published information, schools, and professional associations -- are used less frequently and are of less importance than all other sources of technical information.

Gatekeeper Activity Comparison. Wilcoxon Rank Sum Tests (alpha = 0.05) were conducted to compare the gatekeeping activity within the three demographic characteristics (organization, years of service, and education). The null hypothesis for each of the three tests was that no difference existed between the two populations. None of the tests resulted in rejection of the null hypothesis -- therefore the difference in gatekeeper activity between the three demographic characteristics was not statistically significant. More detailed information including response distributions is found in Appendix C.

Database Use. Six WR-ALC engineers reported using automated database services. None of the ASD engineers reported using them. Table 12 shows the frequency of response for reasons why database services are not used.

TABLE 12

REASONS WHY DATABASE SERVICES ARE NOT USED

Reason	WR-ALC	ASD
-- Not aware of database services	7	12
-- Not convenient	12	10
-- Does not contain information relevant to my needs	3	7
-- Not applicable	7	3

Investigative Question 2. This question addressed the perceived criteria that affect access to sources of technical information external to one's organization. Those surveyed were asked to rate suggested information flow criteria on a scale of "1" (significant barrier) to "5" (significant facilitator), with "3" (no effect) serving as a neutral point. The hypothesis test for ordinal data (Wilcoxon Rank Sum Test) at a 0.1 overall alpha was applied to the sample data (null hypothesis = no difference between the sampled population distributions), to compare the perceptions of each criterion within the three demographic characteristics (organization, years of experience, and level of education).

Table 13 shows the survey results. None of the criteria were perceived as information flow facilitators -- all were perceived as barriers. The mean perceived barrier score and the percentage of respondents who rank each criterion as "no effect" is shown in columns 2 and 3, respectively, in Table 13. If the hypothesis tests indicated a significant difference within the perceptions of each criterion reported by the three demographic profiles, it is so indicated in column 4, and the group with the lower mean score (greater perceived barrier) is shown in column 5. The barriers are arranged in order of decreasing magnitude. More detailed information including response distributions is found in Appendix D.

TABLE 13

BARRIERS TO TECHNICAL COMMUNICATION

Criteria	percent no effect	overall mean	reject null	lower score
I. Time avail. to seek info. outside of org.	25.4%	2.01	None	N/A
L. Organization priorities that affect innovation	30.5%	2.01	None	N/A
J. Resistance to change	32.2%	2.14	None	N/A
E. Technology class. restrictions (secrecy)	38.7%	2.18	None	N/A
F. Information volume -- data quant. req'd to search for relevant info.	38.7%	2.19	None	N/A
D. Contractor proprietary data rights	45.2%	3.24	None	N/A
G. Database accessibility	40.1%	2.32	None	N/A
N. Communication between AF and other Services	33.3%	2.36	None	N/A
M. Communication between AFSC and AFLC	38.1%	2.39	WR/ASD	WR
B. Complexity of journal literature	50.7%	2.49	None	N/A
A. Technical jargon used by other orgs	42.8%	2.51	None	N/A
H. Incentives to innovate	49.1%	2.65	None	N/A
C. Propensity to publish one's results	45.0%	2.73	None	N/A
K. Willingness to access external sources of info	41.9%	2.77	None	N/A

The only statistically significant demographic comparison concerns the degree of technical communication between Air Force Systems Command (AFSC) product divisions and the Air Force Logistics Command (AFLC) Air Logistics Centers (ALC's). The WR-ALC engineers perceived the degree of technical communication between the two organizations to be a greater barrier than did the engineers within ASD. This finding is consistent with the conclusions reached by Colonel Grapes in his speech, as noted in chapter 1 of this paper. No other trends were evident within the demographic characteristics and the perceptions of each criterion.

A wide variation seemed evident between the overall mean perception of each criterion. Therefore a Kruskal-Wallis test was conducted to test the null hypothesis of no difference between the population distributions associated with each criterion. The resultant Chi-Square statistic (56.03) and associated p-value ($p < .0001$) indicated that the populations were indeed statistically different. Additional Kruskal-Wallis tests were used to rank the barriers in order of decreasing magnitude, as shown in Table 13 above. Although none of the criteria were considered to be significant barriers (mean scores less than 2), the top five criteria (I, L, J, E, and F) could be considered as minor barriers (mean scores of 2.2 or less). Items D, G, N, M, and B could be construed as very minor barriers (scores from 2.21 to 2.50). The remaining four items (A, H, C, and

K) were clustered from 2.51 to 2.77, an indication that these criteria were considered as insignificant barriers to the flow of technical information from external sources into one's organization.

Spearman Rank Correlation Tests were done to assess the relationship between source frequency of use/importance and the five most significant barriers (I, L, J, E, and F). A negative, but weak (-.3811) correlation was noted between resistance to change and the perceived importance of informal external sources of information. No other significant correlations were found.

Investigative Question 3. This question asked the respondents to provide their own suggestions for communication opportunities that would improve the flow of technical knowledge into and within their organization. The responses, along with the number of times each was mentioned, are summarized below.

- improve on-line database access -- "a terminal on every desk" (6)
- provide office funds for purchasing technical literature (journals, etc.) (5)
- establish/improve tech libraries at WR-ALC (4)
- provide opportunities for schooling, seminars, training, contractor plant tours (3)
- standardize and automate the individual organization filing systems -- connect all organizations via computer for general access (3)
- hold regular office meetings to discuss applicable existing and proposed technologies (2)

- each office have a focal point responsible for maintaining a technical database (2)

- change funding policy on AFLC engineering efforts from O&M to project funds (1)

- educate new hires on organization's functional charter (1)

- contract for a government engineering publication (like Airman magazine, etc) -- why not one for engineers? (1)

- improve the ability to understand "where to go" to contact appropriate government office for information (organization charts, addresses) (1)

- improve management's technical competence of engineering issues (1)

- provide training/awareness of database systems (1)

- establish and maintain formal "hands on" on-the-job training (1)

- establish weekly base-wide technical briefings (The Foreign Technology Division at WP-AFB now conducts weekly intelligence briefings, including relevant information and points of contact for further help.)

V. Findings and Recommendations

Assumptions and Limitations

Although the findings can not be statistically generalized to groups of engineers other than those surveyed in this research, the findings can be used logically to predict similar technical communication behavior elsewhere.

An important limitation is to recognize that since this was exploratory, ex post facto research and not an experiment, this study does not purport to show causality. In particular, it cannot be said that the use or non-use of certain sources of technical information causes some engineers to perceive technical communication barriers differently than other engineers.

Key Findings

The key findings resulting from this research were:

1. No differences were found within each of the three demographic characteristics (organization, years of federal experience, and educational degree) and the frequency of use of each of the four sources. There were, however, significant differences between the overall frequency of use of the four sources. Engineers in this research were found to use informal internal sources (oral discussion with others within one's organization) to obtain technical information significantly more often than any other source.

Informal internal sources were also found to be perceived as more important than than any other source. This could be due to the "law of least effort" expressed by Gerstberger and Allen (20:277), which states that people are more likely to choose an information source based on ease of use than on the amount or quality of expected information. Indeed, it is generally easier to ask someone in one's own organization for a problem solution than it is to ask people from other organizations or attempt to research literature.

2. Engineers who had completed graduate coursework perceived formal internal information sources to be more important than did engineers who had undergraduate degrees only. A possible reason may be due to the positive, weak correlation (0.3429) found between the engineers' rank/grade level and their highest level of formal education. Engineers in the higher grades are probably more responsible for developing and implementing items such as in-house technical reports or statements of work, and may also have greater access to formal program reviews/meetings, than do engineers in the lower grades.

3. Formal external sources (documents or journals published from sources outside one's organization, schools, and professional associations) were found to be used less frequently and of less importance than all other sources of information. The low reported frequency of use appears to be consistent with the "law of least effort" phenomenon

noted in finding #1 above. However, the low perceived importance of formal external sources is surprising. One would expect that these sources would represent the most credible, valid information available, due to the supporting research and exhaustive professional peer review that must support much published technical information. The concept of regularly valuing the oral opinion of one's peers within one's organization over all published technical information sources seems risky indeed.

4. No significant differences were found between the reported gatekeeping activities of the Warner Robins Air Logistics Center (WR-ALC) engineers versus those of the Aeronautical Systems Division (ASD) engineers. This finding was unexpected. The researcher had thought the ASD engineers, owing to their overall charter of new system development, would demonstrate significantly higher gatekeeping behavior than the WR-ALC engineers. In addition, the researcher had believed the proximity, amount and variety of local industry and universities to Wright-Patterson AFB would serve to enhance ASD gatekeeping activity. Perhaps the limited technical library availability at WR-ALC may require engineers there to actively engage in gatekeeping behavior.

5. Database use -- a formal, external source -- was reported by 20% of the WR-ALC engineers. None of the ASD engineers reported using database services. A reasonable

explanation for this disparity may involve the greater ASD accessibility to technical libraries, including the Wright Research and Development Center library and the Air Force Institute of Technology library at Wright-Patterson AFB as noted in finding #4 above.

The two most frequently reported reasons for not using database services were 1) the fact that database services were not perceived to be convenient (36%), and 2) a lack of awareness of database services (31%). These findings are consistent with the results obtained by Hubbard and Zacardo in their research of DTIC use by the Army (24:77). This researcher's only complaint about DTIC convenience concerns the amount of time required for receipt of paper and microfiche copies of DTIC reports. Efforts by DTIC and technical library personnel to train prospective users about use of the DROLS (Defense RDT&E On-Line System) should help to reduce the time delays for document receipt.

Since the DTIC database system is designated as "the central focus for the (DoD) scientific and technical information program" (50:65), it should follow that more should be done to improve widespread awareness of DTIC and its available services, such as DTIC's DROLS and Current Awareness Bibliography (CAB) programs.

6. The two most significant perceived barriers that impede technical communication with sources outside one's organization were a) a lack of time to seek information

outside the organization, and b) organizational priorities that discourage innovation, such as a lack of support for facilities or personnel dedicated to gathering and disseminating technical information. Several WR-ALC engineers reported that the limited technical libraries available made it difficult for them to obtain technical information. Another WR-ALC engineer noted that proposed funding for improved systems does not compete well against funding for normal replacement or repair.

Both ASD and WR-ALC engineers urged that formal, designated technical positions be established within their organizations to gather and disseminate technical information.

Three other barriers, although less significant, were c) resistance to change, d) secrecy, and e) the perception that the sheer volume of information available is too great to effectively search for relevant information.

Resistance to change is a barrier that often appears in research directed at the problems of technology diffusion, and is difficult to eliminate. The negative, but weak correlation between resistance to change and the perceived importance of informal, external sources of information (dialogue with contractors, peers from other organizations, and professional society contacts) suggests that as resistance to change increases, the perceived importance of informal external information sources decreases. The weak

correlation value indicates that it may or may not be meaningful. Further research is necessary to verify whether a correlation actually exists.

Secrecy is a deliberate barrier that is necessary in the interests of national security, and probably should not be eliminated. The "too much information" barrier can be relatively easily reduced by encouraging more widespread use of database bibliography services such as those provided by DTIC.

7. The WR-ALC engineers perceived that a lack of technical communication between AFLC and AFSC was a barrier. The ASD engineers did not share this view. They perceived that the existing level of communication is satisfactory. However, Col Grapes (HQ AFLC) argues that the identification of system maintenance requirements to AFSC engineers is "insufficient and not timely" (2:27). He also urges that AFLC engineers enhance their technical knowledge through increased interaction with the personnel and expertise from the Air Force Wright Research and Development Center.

Recent Congressional and DoD interest in system maintainability and associated life cycle costs may indirectly help to improve AFSC/AFLC technical communication. In addition, Defense Secretary Cheney's efforts to streamline weapon system acquisition and management may result in a major restructure of Air Force weapon system acquisition and logistical support (10:14).

The results of his efforts and the associated impact is yet to be seen.

8. The five most frequently mentioned suggestions for improving the flow of technical knowledge into one's organization were directly related to improving access to formal external information sources. These suggestions included improving on-line database access, allocating funds to procure technical literature, establishing/improving technical libraries at air logistics centers, providing opportunities for training and tours, and standardizing, automating and connecting individual organization filing systems for general access.

Comparison of Findings with Creighton-Jolly Model

The Creighton-Jolly model (discussed in chapter 2) contained a list of intrinsic and extrinsic factors that can affect information flow. None of the extrinsic factors (capacity, gatekeepers, source credibility, rewards, and willingness to accept change) were perceived by the respondents to be barriers to technical communication. A comparison of each intrinsic factor with the results of this research is shown below.

Documentation. Documentation -- the ways that information is defined, organized and presented -- appeared not to significantly impede information flow. Secrecy was the only one of five potential documentation survey criteria that ranked as one of the top five barriers. Three other

documentation criteria, including the complexity of journal literature, technical jargon used by other organizations, and the propensity of engineers to publish their results, scored in the bottom five, and thus were not considered as barriers. [However, the perception of what is or is not a barrier depends on one's perspective. DTIC research indicates that a lack of publication activity is a continuing problem (15; 24)].

Distribution. Distribution refers to the channels through which information flows. Distribution-related factors appeared to be perceived as barriers to technical communication. Two distribution criteria -- a lack of time available to seek sources outside of one's organization, and the sheer volume of information that must be processed to obtain relevant information -- ranked in the top five barriers. The reported lack of use of database services was surprising, considering the barriers mentioned above. An increased use of automated databases, particularly database bibliographies and abstracts, would help one to quickly attain relevant information. However, to realize the maximum potential of databases, engineers must be willing to report their findings to, as well as extract information from these services. DTIC's problems in obtaining technical information are well documented, as noted above.

The high rate of personnel rotation reported by the respondents should positively impact information distribu-

tion. However, the sample data did not indicate the extent of the job transfers -- whether they were primarily within one geographic location (and associated organizations), or between a variety of locations.

Most of the suggestions for improving technical communication centered on distribution factors such as automated database access and opportunities for training.

Organization. Organization-related criteria were perceived as two of the top five barriers to communication flow. These included resistance to change and priorities that affect innovation. These barriers seem to appear in study after study (3; 24; 30; 39), and may indeed prove to be the most difficult to eliminate.

Conclusion

Past research shows that one of the greatest barriers to the diffusion of technology is a simple lack of awareness that a technology exists, or knowledge of its risks and benefits. If the Air Force is to improve the quality of its fielded weapon systems within the constrained budgets currently available, it must capitalize on mature, proven technologies as much as possible. A principal method of ensuring secondary use of mature technologies is to diffuse awareness of the technologies by encouraging technical communication with sources external to one's organization. To achieve this end, this author recommends the following steps be taken:

1. Recommend that efforts be conducted to increase the awareness and use of automated database services such as DTIC. A general awareness and use of database services would help eliminate the barriers of "too much information" and lack of time to seek information from external sources. These efforts could be shared by technical library personnel, DTIC, and engineering management. An improved awareness may help to reduce the perceptions of a lack of convenience of database access.

2. Recommend that engineers be encouraged to document and publish their technical achievements. Potential inducements could include peer recognition and encouragement of the presentation of papers at technical society meetings and DoD symposiums.

3. Recommend that engineers meet periodically with their peers from other organizations to exchange technical information. These meetings could provide a forum to diffuse awareness of contractor and Government innovations or methods that improve product performance and quality.

4. Recommend that communication with formal and informal technical sources external to one's organization be encouraged as much as possible. This encouragement could occur in the form of budgets for training and technical journals, and allowance of time for attendance at short courses, seminars, and functions like the Blue-Two program sponsored by AFCOLR.

This research, however, showed that a curious dichotomy seems to exist between the respondents' emphasis on suggestions for improving access to formal external sources, in relation to their lack of use of and relatively low importance they place on these same sources. A shortcoming of this research is that it did not address why formal external sources are not perceived to be important. Greater access to formal external sources may or may not cause them to be used more frequently and perceived as more important. Therefore this author recommends that efforts that enhance access to formal external sources (such as the establishment of libraries or funding allocations for purchasing technical literature) be conducted cautiously.

Suggestions for Further Research

1. Recommend that this study be repeated next year to verify the reliability of the results of this research.

2. Recommend this research be expanded to cover a larger sample size, to extend the generalization of this research to all defense systems engineers. This larger sample should include engineers affiliated with nonprofit defense engineering support corporations, such as MITRE (Lexington MA) or the Aerospace Corporation (Los Angeles CA).

3. Recommend that the research conducted by Allen et al. (5) on the effect of technical information requirements

as a function of program timing be applied to a defense system procurement setting.

4. Recommend that research be conducted to assess how the amount and content of current MIL-STDs and other specification standards are perceived to affect defense engineers' capacity for innovativeness and propensity to seek better ways to design and manufacture weapon systems.

5. Recommend that efforts be conducted to integrate existing technical communication survey instruments into a standard tool with proven reliability and validity.

Appendix A: Pre-Survey

DEFENSE ENGINEERING

TECHNICAL COMMUNICATION

PRE-SURVEY

Scope: This pre-survey is being done to determine the appropriate criteria for use on a survey that will be accomplished this June. Specifically, I ask for your opinion on whether the following items should or should not be included in my survey instrument. In addition, I want you to suggest additional items for inclusion that I may have missed. Please do not judge your own organization when completing this pre-survey, but instead use your past experience and professional judgement.

Please note that your participation is completely voluntary, but I would certainly appreciate your help. Your individual response will be combined with others and will not be attributed to you personally.

Instructions: Please circle the number (e.g. 1, 2, etc) that corresponds to your selected response to each question.

Part I.

Are the following sources of information relevant to an engineer when he/she seeks technical information appropriate to his/her job?

Yes, this source is highly relevant.	This source is sometimes used	No, this source is not relevant
1	2	3

A. (Formal, documented Sources Within My Organization)

a.	In-house Technical Reports	1	2	3
b.	Newsletters	1	2	3
c.	Old Specs or Statements of Work	1	2	3
d.	Attendance at Program Reviews/Meetings	1	2	3
e.	Other _____	1	2	3

Part I (Continued)

Yes, this source is highly relevant.	This source is sometimes used	No, this source is not relevant
1	2	3

B. (Formal, documented Sources External to My Organization)

a.	Government Technical Reports/Mil-Stds	1	2	3
b.	Technical Journals/Periodicals	1	2	3
c.	Attendance at Technical Seminars	1	2	3
d.	Text Books/Specialized Technical Books	1	2	3
e.	Schools/Training	1	2	3
f.	Contractor Reports	1	2	3
g.	Other_____	1	2	3

C. (Informal, Personal Contacts Within My Organization)

a.	Informal Technical Meetings	1	2	3
b.	Dialogue with Associates, Colleagues	1	2	3
c.	Dialogue with Supervisor	1	2	3
d.	Other_____	1	2	3

D. (Informal, Personal Contacts External to My Organization)

a.	Informal Technical Meetings	1	2	3
b.	Dialogue with Associates, Colleagues	1	2	3
c.	Professional Society Contacts	1	2	3
d.	Dialogue with Contractors	1	2	3
e.	Other_____	1	2	3

Do you have suggestions for any additional sources of information that should be included in the survey?

Part II Criteria that Affect Communication Flow

In this part I'm attempting to identify criteria that may affect the flow of technical information between engineering organizations. In other words, do the following criteria represent items I should ask in my questionnaire? If you feel that any criterion is confusing or should be re-worded in any way, feel free to indicate changes! Please use the scale shown below to indicate your estimate of the relevancy of each criterion to communication flow:

Criterion highly relevant to technical information flow	Criterion moderately relevant to technical information flow	Criterion not relevant to information flow
1	2	3

a.	Ability to Understand Technical Jargon used by other Organizations	1	2	3
b.	Ability to Comprehend Professional Journal Literature	1	2	3
c.	Documentation - Likelihood of Writing About Technical Accomplishments	1	2	3
d.	Contractor Proprietary Data Rights	1	2	3
e.	Technology Classification Restrictions	1	2	3
f.	Information Volume -- Time Required to Search for Relevant Information	1	2	3
g.	Database Services -- Ease of Use	1	2	3
h.	Rewards or Incentives to Innovate	1	2	3
i.	Availability of Time to Seek Information Outside of Organization	1	2	3
j.	Resistance to Change	1	2	3
k.	Willingness to Access External Sources	1	2	3

Part II (Continued)

	Criterion highly relevant to technical information flow	Criterion moderately relevant to technical information flow	Criterion not relevant to information flow
	1	2	3
l.	Organization priorities that Affect Innovation	1	2 3
m.	Communication between AFSC Product Divisions and AFLC ALC's	1	2 3
n.	Communication between AF Product Divisions and other Services (Navy, Army, etc)	1	2 3
o.	Other (Please Explain)_____ _____ _____ _____	1	2 3

Do you have suggestions for any additional criteria that I may have missed?

Thank you for your help!

Appendix B: Survey

USAF SCN 89-32

DEFENSE ENGINEERING

TECHNICAL COMMUNICATION

SURVEY

Background: The Air Force Coordinating Office for Logistics Research (AFCOLR) is sponsoring AFIT research into the methods of technical communication used by engineers when seeking to maintain "state-of-the-Art" knowledge in their discipline areas.

Purpose: To identify technical communication barriers and facilitators, as perceived by selected Air Force Systems Command And Air Force Logistics Command engineers, that affect the diffusion of mature (empirically proven) technologies from external sources into their organizations. The results of this research will be basic inputs to a published Air Force Institute of Technology, School of Systems and Logistics, student thesis.

Scope: This survey will ask how selected engineers obtain and disseminate technical information, and will request the engineers to rate their perceptions of proposed criteria that affect technical communication. A census of engineers from organizations selected from AFSC and AFLC will be requested to fill out the attached survey.

Instructions: The survey is composed of four parts. For Part I, please circle the number [e.g. (1), (2), etc] that corresponds to the correct answer to each question. Please note that your "organization" is defined as either an Air Logistics Center (ALC) or a Product Division. For example, if you are an AFSC engineer, then you work for a specific Product Division. Product Divisions at other bases and other organizations (laboratories, test wings, etc) would constitute separate organizations. AFLC ALC's would follow a similar concept. Please retain this definition when completing each part of the survey.

For Parts II, III, and IV, please follow the instructions provided at the beginning of each section.

TECHNICAL INFORMATION SURVEY USAF SCN 89-32

Part I Demographic Information.

1. What is your organization? (1) ALC (2) Product Division

2 Are you a supervisor or non-supervisor? (1) Supervisor (2) Nonsupervisor

3. Are you a military or civilian worker? (1) Military (2) Civilian

4. What is your rank or grade level?

(1) GS-9 or 2Lt
(2) GS-11 or 1Lt
(3) GS-12 or Capt
(4) GS/GM-13 or Major
(5) GS/GM 14 or above or Lt Col or above

5. How long have you performed Government service?

(1) Less than 5 years
(2) 5 but less than 10 years
(3) 10 but less than 15 years
(4) 15 but less than 20 years
(5) 20 or more years

6. How long have you worked in your present organization?

(1) Less than 5 years
(2) 5 but less than 10 years
(3) 10 but less than 15 years
(4) 15 but less than 20 years
(5) 20 or more years

7. To which age group do you belong?

(1) 21-25 years
(2) 26-35 years
(3) 36-45 years
(4) 46-55 years
(5) 56 years or more

8. What is your highest level of formal education?

(1) High School
(2) Bachelors Degree
(3) Graduate Work/No Degree
(4) Masters Degree
(5) Doctorate

Part II Sources of Information

Questions 9 through 12 present a list of potential sources of technical information. Sources are classified in formal and informal categories, and whether they are found internal or external to the organization (defined as either a Product Division or ALC). Formal sources are defined as those sources that are documented or meetings that are advertised and held specifically for purposes of advancing or disseminating technical information. Informal sources include all other sources.

For the following four questions, please indicate your frequency of use of each source (the number of times per month you obtain technical information from each source), and how important each source is (in terms of relevance, timeliness, and reliability, for example) to your job. Please indicate your frequency of use and importance of each source by circling the appropriate number for each source according to the scales below:

Frequency of Use (Times per month you obtain information)					Importance				
None	1-2 Times	3-4 Times	5-6 Times	>6 Times	Not Important	Somewhat Important	Important	Very Important	Extremely Important
1	2	3	4	5	1	2	3	4	5

9. Formal Sources Within My Organization	Frequency of Use	Importance
a. In-house Technical Reports	1 2 3 4 5	1 2 3 4 5
b. Old Specs or Statements of Work	1 2 3 4 5	1 2 3 4 5
c. Attendance at Program Reviews/Meetings	1 2 3 4 5	1 2 3 4 5
d. Other _____	1 2 3 4 5	1 2 3 4 5

10. Formal Sources External to My Organization		
a. Government Technical Reports/Mil-Stds	1 2 3 4 5	1 2 3 4 5
b. Technical Journals/Periodicals	1 2 3 4 5	1 2 3 4 5
c. Attendance at Technical Seminars	1 2 3 4 5	1 2 3 4 5
d. Text Books/Specialized Technical Books	1 2 3 4 5	1 2 3 4 5
e. Schools/Training	1 2 3 4 5	1 2 3 4 5
f. Contractor Reports	1 2 3 4 5	1 2 3 4 5
g. Other _____	1 2 3 4 5	1 2 3 4 5

11. Informal Contacts Within My Organization		
a. Informal Technical Meetings	1 2 3 4 5	1 2 3 4 5
b. Dialogue with Associates, Colleagues	1 2 3 4 5	1 2 3 4 5
c. Dialogue with Supervisor	1 2 3 4 5	1 2 3 4 5
d. Other _____	1 2 3 4 5	1 2 3 4 5

Frequency of Use (Times per month you obtain information)					Importance				
None	1-2 Times	3-4 Times	5-6 Times	6 Times	Not Important	Somewhat Important		Very Important	Extremely Important
1	2	3	4	5	1	2	3	4	5

12. Informal Contacts External to My Organization

	Frequency of Use	Importance
a. Informal Technical Meetings	1 2 3 4 5	1 2 3 4 5
b. Dialogue with Associates, Colleagues	1 2 3 4 5	1 2 3 4 5
c. Professional Society Contacts	1 2 3 4 5	1 2 3 4 5
d. Dialogue with Contractors	1 2 3 4 5	1 2 3 4 5
e. Other_____	1 2 3 4 5	1 2 3 4 5

13. On average, how many times per month do you provide technical information upon request to people within your organization?

(1) 0
(2) 1-2 times
(3) 3-4 times
(4) 5-6 times
(5) More than 6 times

14. On average, how many times per month do you provide technical information upon request to people external to your organization?

(1) 0
(2) 1-2 times
(3) 3-4 times
(4) 5-6 times
(5) More than 6 times

15. Do you use automated database information services? [For example: the Defense Technical Information Center (DTIC) or the National Technical Information Service (NTIS)]

_____ a. Yes _____ b. No

16. If you do not use database information or services, why not?

_____ a. Not aware of database services

_____ b. Not convenient to use

_____ c. Does not contain information relevant to my needs

_____ d. Other (Please list)_____

_____ e. Not Applicable

Part III Criteria that Affect Communication Flow

This survey is investigating communication barriers and facilitators that affect widespread awareness of technical advances that are relevant to our work. In your opinion, how do the following criteria affect your technical communication with sources external to your organization? Please rate your assessment of the magnitude and type (barrier or facilitator) of each criteria by circling the number opposite to each item according to the following scale:

Significant Barrier	Minor Barrier	No Effect	Minor Facilitator	Significant Facilitator
1	2	3	4	5

a.	Technical Jargon Used by other Organizations	1	2	3	4	5
b.	Complexity of Professional Journal Literature	1	2	3	4	5
c.	Publication Activity - Probability of Engineers to Report Their Findings in the Open Literature (Tech reports, etc)	1	2	3	4	5
d.	Contractor Proprietary Data Rights	1	2	3	4	5
e.	Technology Classification Restrictions (Secrecy)	1	2	3	4	5
f.	Information Volume -- Data Quantity Required to Search for Relevant Information	1	2	3	4	5
g.	Accessibility of Database Information Services as an Information Source	1	2	3	4	5
h.	Incentives (Rewards, Recognition) to Innovate (or lack of)	1	2	3	4	5
i.	Availability of Time to Seek Information Outside of Organization	1	2	3	4	5
j.	Resistance to Change	1	2	3	4	5
k.	Willingness of Engineers to Access External Sources of Information	1	2	3	4	5

Significant Barrier	Minor Barrier	No Effect	Minor Facilitator	Significant Facilitator
1	2	3	4	5

l.	Organization Priorities that Affect Innovation (Example: Production Quantity Versus Quality Improvement)	1	2	3	4	5
m.	Communication between AFSC Product Divisions and AFLC ALC's	1	2	3	4	5
n.	Communication between AF Product Divisions or ALC's and other Services (Navy, Army, etc)	1	2	3	4	5
o.	Other (Please Explain)_____ _____ _____ _____	1	2	3	4	5

Part IV Communication Opportunities.

As a user of scientific and technical information, we would like you to tell us what methods or policies would help improve the flow of technical knowledge into and within your organization.

_____

_____

_____

_____

_____

_____

Thank you for your support!

Appendix C: Results for Investigative Question 1

This appendix presents the descriptive statistics and analysis of data collected by Part II of the survey questionnaires. Part II asked the survey respondents to indicate their frequency of use and perceived importance of four sources of information, including a) formal sources internal to their organization, b) formal external sources, c) informal internal sources, and d) informal external sources. The Wilcoxon Rank Sum test for ordinal data was used for analysis. Since the test was to be replicated four times (once for each source) for each of the demographic characteristics (organization, years of experience, and education), the overall Type 1 error (falsely claiming significant differences between populations) was controlled using the Bonferroni inequality (35:147). Under this method, the overall alpha of 0.1 was divided by the number of tests (four) to result in an alpha of 0.025 per test. This resulted in a critical statistic of 2.24 (37:A-2). The personal computer program STATISTIX was used to analyze the data. STATISTIX uses a method proposed by Snedecor and Cochran (46:144) that uses the rank sum results to calculate the normal approximation test statistic. The null hypothesis of no difference between the two distributions was rejected if the test statistic was larger than the critical statistic.

The total response distributions, mean scores, percentage of respondents indicating they do not use the source, or the source is not important, and results of the hypothesis tests are shown below.

Frequency of Use. The frequency of use scale was partitioned from "1" (information not obtained from this source) to "5" (information obtained more than six times per month from this source).

A. Formal Internal Sources

Total Responses	
Scale	N
1	12
2	37
3	9
4	3
5	2

Category	Mean Score
Total	2.41
WR-ALC	2.41
ASD	2.42
0-14 yrs	2.42
15 or more yrs	2.38
Grad	2.51
Under	2.21

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	0.28	Accept
0-14/15 or more	2.24	0.92	Accept
Grad/Under	2.24	0.64	Accept

Percentage of respondents indicating they use this source one time or less per month: 19%

This research indicates that the overall mean frequency of use score for formal internal sources was 2.41 times per month. The hypothesis tests suggest that the three demographic groups did not differ significantly in their frequency of use of this source.

B. Formal External Sources

Total Responses	
Scale	N
1	24
2	30
3	6
4	2
5	1

Category	Mean Score
Total	2.19
WR-ALC	2.21
ASD	2.17
0-14 yrs	2.32
15 or more yrs	2.03
Grad	2.24
Under	2.11

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	0.36	Accept
0-14/15 or more	2.24	1.77	Accept
Grad/Under	2.24	0.52	Accept

Percentage of respondents indicating they use this source one time or less per month: 38.1%

This research indicates that the mean frequency of use score for formal external sources was 2.19 times per month. The hypothesis tests suggest that the three demographic groups did not differ significantly in their frequency of use of this source.

C. Informal Internal Sources

Total Responses	
Scale	N
1	4
2	12
3	25
4	18
5	4

Category	Mean Score
Total	3.38
WR-ALC	3.33
ASD	3.43
0-14 yrs	3.37
15 or more yrs	3.39
Grad	3.35
Under	3.44

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	0.20	Accept
0-14/15 or more	2.24	0.15	Accept
Grad/Under	2.24	0.47	Accept

Percentage of respondents indicating they use this source one time or less per month: 6.3%

This research indicates that the overall mean frequency of use score for informal internal sources was 3.38 times per month. The hypothesis tests suggest that the three demographic groups did not differ significantly in their frequency of use of this source.

D. Informal External Sources

Total Responses	
Scale	N
1	14
2	27
3	15
4	6
5	1

Category	Mean Score
Total	2.61
WR-ALC	2.60
ASD	2.62
0-14 yrs	2.46
15 or more yrs	2.79
Grad	2.57
Under	2.68

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	0.18	Accept
0-14/15 or more	2.24	1.17	Accept
Grad/Under	2.24	0.43	Accept

Percentage of respondents indicating they use this source one time or less per month: 22.2%

This research indicates that the overall mean frequency of use score for informal external sources was 2.61 times per month. The hypothesis tests suggest that the three demographic groups did not differ significantly in their frequency of use of this source.

Kruskal-Wallis Tests for Overall Frequency of Use

Six Kruskal-Wallis one-way nonparametric analysis of variance tests were conducted to compare the overall frequency of use of the four sources. Using the Bonferroni approach (35:147), the overall alpha of 0.1 was divided by the number of tests (six) to result in individual test alphas of 0.016. The computer program STATISTIX was used to conduct the Kruskal-Wallis tests. If the test statistic P-value was lower than the test alpha, then at least two of the distributions being tested were declared significantly different. The mean ranks of the distributions were then compared to determine the direction of the difference. The results are shown below.

Test	Kruskal-Wal Statistic	P-value	Sig Diff	Higher Mean
FI-FE-II-IE	51.97	0.000	Yes	Unknown
FI-FE	3.22	0.072	No	None
FI-II	30.69	0.000	Yes	II
FI-IE	1.50	0.220	No	None
FE-IE	7.36	0.006	Yes	IE
FE-II	42.18	0.000	Yes	II
II-IE	18.87	0.000	Yes	II

Note: FI = Formal Internal sources, FE = Formal External sources, II = Informal Internal sources, IE = Informal External sources.

Source Perceived Importance. The perceived importance scale was partitioned from "1" (source is not important) to "5" (source is extremely important).

A. Formal Internal Sources

Total Responses	
Scale	N
1	4
2	17
3	30
4	9
5	2

Category	Mean Score
Total	3.14
WR-ALC	2.94
ASD	3.34
0-14 yrs	3.16
15 or more yrs	3.12
Grad	3.32
Under	2.82

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	2.17	Accept
0-14/15 or more	2.24	0.25	Accept
Grad/Under	2.24	2.23	Reject

Percentage of respondents indicating they perceive this source as less than "somewhat important": 33.8%

This research indicates that the overall mean perceived importance score for formal internal sources was 3.14 (slightly higher than "important"). The hypothesis tests suggest that persons who have completed graduate coursework value formal internal sources differently than their undergraduate counterparts. The mean graduate score was one-half point higher than the mean undergraduate score.

B. Formal External Sources

Total Responses	
Scale	N
1	7
2	26
3	22
4	5
5	2

Category	Mean Score
Total	2.90
WR-ALC	2.91
ASD	2.89
0-14 yrs	2.99
15 or more yrs	2.78
Grad	2.94
Under	2.82

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	0.33	Accept
0-14/15 or more	2.24	1.29	Accept
Grad/Under	2.24	0.54	Accept

Percentage of respondents indicating they perceive this source as less than "somewhat important": 46.7%

This research indicates that the overall mean perceived importance score for formal external sources was 2.90 (slightly less than "important"). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceived importance of this source.

C. Informal Internal Sources

Total Responses	
Scale	N
1	3
2	6
3	28
4	18
5	7

Category	Mean Score
Total	3.58
WR-ALC	3.74
ASD	3.41
0-14 yrs	3.59
15 or more yrs	3.57
Grad	3.62
Under	3.50

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	0.81	Accept
0-14/15 or more	2.24	0.39	Accept
Grad/Under	2.24	0.61	Accept

Percentage of respondents indicating they perceive this source as less than "somewhat important": 14.5%

This research indicates that the overall mean perceived importance score for informal internal sources was 3.58 (between "important" and "very important"). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceived importance of this source.

D. Informal External Sources

Total Responses	
Scale	N
1	6
2	22
3	20
4	13
5	1

Category	Mean Score
Total	3.03
WR-ALC	3.01
ASD	3.05
0-14 yrs	2.95
15 or more yrs	3.13
Grad	3.02
Under	3.05

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	0.29	Accept
0-14/15 or more	2.24	0.79	Accept
Grad/Under	2.24	0.06	Accept

Percentage of respondents indicating they perceive this source as less than "somewhat important": 45.2%

This research indicates that the overall mean perceived importance score for formal external sources was 3.03 ("important"). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceived importance of this source.

Kruskal-Wallis Tests for Overall Perceived Importance

Six Kruskal-Wallis one-way nonparametric analysis of variance tests were conducted to compare the overall perceived importance of the four sources. Using the Bonferroni approach (35:147), the overall alpha of 0.1 was divided by the number of tests (six) to result in individual test alphas of 0.016. The computer program STATISTIX was used to conduct the Kruskal-Wallis tests. If the test statistic P-value was lower than the test alpha, then at least two of the distributions being tested were declared significantly different. The mean ranks of the distributions were then compared to determine the direction of the difference. The results are shown below.

Test	Kruskal-Wal Statistic	P-value	Sig Diff	Higher Mean
FI-FE-II-IE	21.28	0.000	Yes	Unknown
FI-FE	3.91	0.047	No	None
FI-II	7.84	0.005	Yes	II
FI-IE	0.29	0.584	No	None
FE-IE	1.12	0.289	No	None
FE-II	18.79	0.000	Yes	II
II-IE	10.59	0.001	Yes	II

Note: FI = Formal Internal sources, FE = Formal External sources, II = Informal Internal sources, IE = Informal External sources.

Gatekeeper Activity

Gatekeeper activity was a construct variable formed by averaging the responses to survey questions 10.b., 12, 13, and 14. The frequency of occurrence scale ranged from "1" (no gatekeeping activity), to "5" (gatekeeping activity more than six times per month).

Total Responses	
Scale	N
1	5
2	22
3	32
4	3
5	0

Category	Mean Score
Total	3.00
WR-ALC	3.11
ASD	2.88
0-14 yrs	2.88
15 or more yrs	3.15
Grad	2.94
Under	3.14

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.24	1.41	Accept
0-14/15 or more	2.24	1.36	Accept
Grad/Under	2.24	1.21	Accept

Percentage of respondents indicating that they do not engage in gatekeeping activity: 8.1%

The overall mean gatekeeping activity score was 3.00 (three to four times per month). The hypothesis tests suggest that the three demographic groups did not differ significantly in their reported gatekeeping activity.

Appendix D: Results for Investigative Question 2

This appendix presents the descriptive statistics and analysis of data collected by Part III of the survey questionnaires. Part III asked the survey respondents to rate a list of criteria as either barriers or facilitators of information flow into their organizations. The five point scale ranged from "1" (significant barrier) to "5" (significant facilitator). The Wilcoxon Rank Sum test for ordinal data was used for analysis. Since the test was to be replicated fourteen times (once for each criterion) for each of the three demographic characteristics (organization, years of experience, and education), the overall Type 1 error was controlled using the Bonferroni inequality (35:147). Using this approach, the overall alpha of 0.1 was divided by the number of tests (fourteen) and rounded to result in an alpha of 0.008 per test. This resulted in a critical test statistic of 2.65 (37:A-5). The personal computer program STATISTIX was used to calculate the normal approximation test statistic based on the rank sum results. The null hypothesis of no difference between the two distributions was rejected if the test statistic was larger than the critical statistic.

The total response distributions, mean (average) scores, percentage of respondents rating the criterion as neither a

facilitator nor a barrier, and results of the hypothesis tests are shown below.

Criterion: A. Technical Jargon Used by other Organizations

Total Responses	
Scale	N
1	1
2	32
3	27
4	3
5	0

Category	Mean Score
Total	2.51
WR-ALC	2.56
ASD	2.45
0-14 yrs	2.49
15 or more yrs	2.54
Grad	2.45
Under	2.62

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	0.88	Accept
0-14/15 or more	2.65	0.29	Accept
Grad/Under	2.65	1.14	Accept

Percentage of respondents indicating the criterion has "no effect": 42.8%

This research indicates that the overall mean perceived barrier score for this criterion was 2.51 (between a "minor barrier" and "no effect"). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: B. Complexity of professional journal literature

Total Responses	
Scale	N
1	6
2	21
3	32
4	2
5	0

Category	Mean Score
Total	2.49
WR-ALC	2.62
ASD	2.37
0-14 yrs	2.32
15 or more yrs	2.61
Grad	2.32
Under	2.85

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	1.06	Accept
0-14/15 or more	2.65	1.26	Accept
Grad/Under	2.65	2.32	Accept

Percentage of respondents indicating the criterion has "no effect": 50.7%

This research indicates that the overall mean perceived barrier score for this criterion was 2.49 (between a "minor barrier" and "no effect"). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions. (The Grad/Under test would have rejected the null hypothesis of no difference had this been an isolated test [where alpha = 0.1 and the associated critical test statistic = 1.64]). The difference in the Grad/Undergrad means is interesting -- one might

normally assume that the more education one receives, the less complicated the literature would seem.

Criterion: C. Publication activity -- probability of engineers to report their findings in the open literature

Total Responses	
Scale	N
1	8
2	14
3	27
4	8
5	3

Category	Mean Score
Total	2.73
WR-ALC	2.64
ASD	2.81
0-14 yrs	2.69
15 or more yrs	2.77
Grad	2.94
Under	2.62

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	0.75	Accept
0-14/15 or more	2.65	0.35	Accept
Grad/Under	2.65	1.07	Accept

Percentage of respondents indicating the criterion has "no effect": 45.0%

The overall mean perceived barrier score for this criterion was 2.73 (close to the "no effect" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: D. Contractor proprietary data rights

Total Responses	
Scale	N
1	14
2	26
3	20
4	0
5	3

Category	Mean Score
Total	2.24
WR-ALC	2.06
ASD	2.39
0-14 yrs	2.22
15 or more yrs	2.25
Grad	2.28
Under	2.21

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	1.36	Accept
0-14/15 or more	2.65	0.21	Accept
Grad/Under	2.65	0.22	Accept

Percentage of respondents indicating the criterion has "no effect": 31.7%

The overall mean perceived barrier score for this criterion was 2.24 (close to the "minor barrier" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: E. Technology classification restrictions (secrecy)

Total Responses	
Scale	N
1	13
2	25
3	24
4	0
5	0

Category	Mean Score
Total	2.18
WR-ALC	2.30
ASD	2.06
0-14 yrs	2.28
15 or more yrs	2.03
Grad	2.07
Under	2.38

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	1.08	Accept
0-14/15 or more	2.65	1.28	Accept
Grad/Under	2.65	1.35	Accept

Percentage of respondents indicating the criterion has "no effect": 38.7%

The overall mean perceived barrier score for this criterion was 2.18 (close to the "minor barrier" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: F. Information volume -- data quantity required to search for relevant information

Total Responses	
Scale	N
1	17
2	19
3	24
4	1
5	1

Category	Mean Score
Total	2.19
WR-ALC	2.26
ASD	2.12
0-14 yrs	2.34
15 or more yrs	2.00
Grad	2.16
Under	2.25

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	0.39	Accept
0-14/15 or more	2.65	1.66	Accept
Grad/Under	2.65	0.41	Accept

Percentage of respondents indicating the criterion has "no effect": 38.7%

The overall mean perceived barrier score for this criterion was 2.19 (close to the "minor barrier" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion. (A significant difference would have been declared between the two "years of experience" groups, had this been an isolated test [alpha = 0.1, t = 1.64]).

Criterion: G. Accessibility of database information services as an information source

Total Responses	
Scale	N
1	18
2	12
3	25
4	5
5	1

Category	Mean Score
Total	2.32
WR-ALC	2.23
ASD	2.41
0-14 yrs	2.41
15 or more yrs	2.22
Grad	2.43
Under	2.10

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	0.86	Accept
0-14/15 or more	2.65	0.85	Accept
Grad/Under	2.65	1.10	Accept

Percentage of respondents indicating the criterion has "no effect": 40.1%

The overall mean perceived barrier score for this criterion was 2.32 (moderately close to the "minor barrier" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: H. Incentives (rewards, recognition) to innovate (or lack of)

Total Responses	
Scale	N
1	11
2	10
3	30
4	9
5	1

Category	Mean Score
Total	2.65
WR-ALC	2.46
ASD	2.83
0-14 yrs	2.54
15 or more yrs	2.81
Grad	2.71
Under	2.55

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	1.42	Accept
0-14/15 or more	2.65	0.91	Accept
Grad/Under	2.65	0.36	Accept

Percentage of respondents indicating the criterion has "no effect": 49.1%

The overall mean perceived barrier score for this criterion was 2.65 (moderately close to the "no effect" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: I. Availability of time to seek information outside of one's organization

Total Responses	
Scale	N
1	25
2	18
3	16
4	2
5	2

Category	Mean Score
Total	2.01
WR-ALC	2.03
ASD	2.00
0-14 yrs	2.11
15 or more yrs	1.89
Grad	2.04
Under	1.95

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	0.01	Accept
0-14/15 or more	2.65	0.97	Accept
Grad/Under	2.65	0.24	Accept

Percentage of respondents indicating the criterion has "no effect": 25.4%

The overall mean perceived barrier score for this criterion was 2.01 (minor barrier). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: J. Resistance to change

Total Responses	
Scale	N
1	15
2	25
3	20
4	2
5	0

Category	Mean Score
Total	2.14
WR-ALC	2.36
ASD	1.93
0-14 yrs	2.22
15 or more yrs	2.03
Grad	2.09
Under	2.25

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	1.88	Accept
0-14/15 or more	2.65	0.89	Accept
Grad/Under	2.65	0.57	Accept

Percentage of respondents indicating the criterion has "no effect": 32.2%

The overall mean perceived barrier score for this criterion was 2.14 (close to the "minor barrier" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion. (A significant difference would have been declared between the two organizations, had this been an isolated test [alpha = 0.1, t = 1.64]).

Criterion: K. Willingness of engineers to access external sources of information

Total Responses	
Scale	N
1	4
2	20
3	26
4	10
5	2

Category	Mean Score
Total	2.77
WR-ALC	2.90
ASD	2.65
0-14 yrs	2.74
15 or more yrs	2.81
Grad	2.83
Under	2.65

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	1.05	Accept
0-14/15 or more	2.65	0.31	Accept
Grad/Under	2.65	0.26	Accept

Percentage of respondents indicating the criterion has "no effect": 41.9%

The overall mean perceived barrier score for this criterion was 2.73 (close to the "no effect" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: L. Organization priorities that affect innovation (example: production quantity versus quality improvement)

Total Responses	
Scale	N
1	21
2	18
3	18
4	2
5	0

Category	Mean Score
Total	2.01
WR-ALC	1.97
ASD	2.07
0-14 yrs	2.12
15 or more yrs	1.88
Grad	2.00
Under	1.91

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	0.42	Accept
0-14/15 or more	2.65	1.02	Accept
Grad/Under	2.65	0.60	Accept

Percentage of respondents indicating the criterion has "no effect": 30.5%

The overall mean perceived barrier score for this criterion was 2.01 (minor barrier). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Criterion: M. Communication between AFSC product divisions and AFLC ALC's

Total Responses	
Scale	N
1	14
2	19
3	24
4	3
5	3

Category	Mean Score
Total	2.39
WR-ALC	2.06
ASD	2.70
0-14 yrs	2.41
15 or more yrs	2.39
Grad	2.53
Under	2.14

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	2.71	Reject
0-14/15 or more	2.65	0.01	Accept
Grad/Under	2.65	1.38	Accept

Percentage of respondents indicating the criterion has "no effect": 38.1%

The overall mean perceived barrier score for this criterion was 2.39 (moderately close to the "minor barrier" point). The hypothesis tests suggest that WR-ALC and ASD differ significantly in their perceptions of whether technical communication barriers exist between AFSC and AFLC.

Criterion: N. Communication between AFSC/AFLC and other services (Navy, Army, etc.)

Total Responses	
Scale	N
1	12
2	24
3	21
4	4
5	2

Category	Mean Score
Total	2.36
WR-ALC	2.53
ASD	2.39
0-14 yrs	2.37
15 or more yrs	2.45
Grad	2.45
Under	2.19

Hypothesis Test Results

Category	Critical Statistic	Test Statistic	Accept/ Reject
WR-ALC/ASD	2.65	0.58	Accept
0-14/15 or more	2.65	0.22	Accept
Grad/Under	2.65	0.79	Accept

Percentage of respondents indicating the criterion has "no effect": 33.0%

The overall mean perceived barrier score for this criterion was 2.36 (moderately close to the "minor barrier" point). The hypothesis tests suggest that the three demographic groups did not differ significantly in their perceptions of this criterion.

Kruskal-Wallis Tests for Overall Criteria

Kruskal-Wallis one-way nonparametric analysis of variance tests were conducted to compare the overall perceptions of each criteria as barriers. Because of the large number of possible comparisons among the fourteen criteria, the Bonferroni method of Type I error control was not used. Instead, the overall alpha of 0.1 was arbitrarily divided by 10 to result in individual test alphas of 0.01. The results are shown below. Means with the same letter grouping are not significantly different.

Grouping	Mean	Barrier
A	2.01	I
A	2.01	L
A B	2.15	J
A B	2.17	E
A B	2.19	F
A B C	2.23	D
A B C D	2.32	G
A B C D	2.36	N
A B C D	2.39	M
A B C D	2.49	B
A B C D	2.51	A
B C D	2.65	H
C D	2.73	C
D	2.77	K

Note: A parametric Analysis of Variance and a Tukey's Comparison of Means test were first conducted to obtain estimates of which means were significantly different. The non-parametric Kruskal-Wallis tests were then done at a 0.01 alpha to verify the results and make additional comparisons.

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Once successfully used, mature (empirically proven) technologies are rarely diffused (remarketed and used) on subsequent systems. One of the greatest barriers to the diffusion of technology is a lack of widespread awareness that a technology exists. The objective of this research was to identify technical communication barriers and opportunities, as perceived by selected Air Force Systems Command (AFSC) and Logistics Command (AFLC) engineers, that affect the diffusion of technologies into their organizations. A survey of 86 selected AFSC and AFLC engineers was conducted in support of the above objective. Overall, the results of the study support the findings of previous research. Recommendations are offered to help improve the widespread awareness of (and hopefully the subsequent use of) mature technologies by defense engineering organizations.